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Effect of organic and inorganic fertilizers on yield and economics of sunflower (*Helianthus annuus* L.) in *rabi* season

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Abstract
The field experiment was carried out during *rabi* 2022 at Experimental Farm of College of Agricultural Biotechnology, Latur to study the effect of organic and inorganic fertilizers on growth and yield of sunflower (*Helianthus annuus* L.) in *rabi* season. The soil of experimental plot was clayey in texture with chemical composition such as low in available nitrogen (125.44 kg ha^{-1}), low in available phosphorous (12.50 kg ha^{-1}) and very high in available potassium (327.41 kg ha^{-1}). Available EC and OC in soil is 0.40 ds m^{-1} and 0.02% respectively. The soil was slightly alkaline in reaction having pH 7.48 and well drained favourable for optimum crop growth.
The experiment was laid out in randomized block design with three replications and eleven treatments. The treatment includes T_1 - Control, T_2 - Biochar (2.5 t ha^{-1}), T_3 - Biochar (5.0 t ha^{-1}), T_4 - Vermicompost (2.5 t ha^{-1}), T_5 - Biochar (2.5 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}), T_6 - Biochar (5.0 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}), T_7 - RDF 100%, T_8 - RDF 100% + Biochar (2.5 t ha^{-1}),T_9 - RDF 100% + Biochar (5.0 t ha^{-1}), T_{10} - RDF 50% + Biochar (2.5 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}), T_{11} - RDF 50% + Biochar (5.0 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}).
The Experimental unit was gross and net plot size of each experimental unit was 5.4 m x 4.5 m and 4.2 m x 3.9 m, respectively. Sowing was done by dibbling method on 20th November, 2022 at spacing of 60 x 30 cm^2 with seed rate 5 kg ha^{-1}. The recommended dose of fertilizer 90:60:30 kg ha^{-1} was applied. The whole dose of PK applied as a basal and nitrogen is applied as per treatments. The application of biochar and vermicompost were taken as per the treatments and applied before sowing the seed. The crop was harvested on 10 March 2023.
The result revealed that the application of RDF 100% + Biochar (5.0 t ha^{-1}) (T_9) recorded significantly highest seed yield (2435 kg ha^{-1}), stalk yield (5739 kg ha^{-1}) and biological yield (8174 kg ha^{-1}), gross monetary return (164606 ₹/ha), net monetary return (112121 ₹/ha), Benefit cost ratio (3.14) which was found significantly superior over rest of treatments of the crop under study.

Keywords: Sunflower, inorganic fertilizers, biochar, vermicompost and randomized

Introduction
Sunflower is an important oilseed crop grown in kharif and rabi seasons across the country. The major sunflower producing countries are Russia, Ukraine, Argentina, China, France, USA, Spain and India. The total area under sunflower crop in world is 29.53 million hectares having production of 58.18 MT and productivity of 1970.3 kg ha^{-1}. The area under sunflower cultivation in India is 0.22 M ha, with the production of 0.23 MT and productivity of 1023 kg ha^{-1} in 2020-21.
Seeds of sunflower are most nutritious and healthy one. Most of the parts of sunflower is used by human being in one side or another way its oil is most valuable. Seed of sunflower contain 35-42% oil, 14-19% protein, 21-27% hull, 7-9% soluble sugar and 30-35% carbohydrates. Sunflower oil has rich source of linoleic acid (64%) which removes cholesterol deposition in the coronary arteries of the heart and thus it is suggested or good for heart patients. Sunflower contains oleic acid- 20% and source of vitamins like A, D, E and B complex and sufficient quantity of calcium and iron. Sunflower oil is used for cooking purpose and it is major part in some margarine and shortening products. Sunflower oil cake contain high amount of quality

protein about 40-44% used as rations for poultry and livestock (Adeleke and Babalola, 2020) [1].

Vermicompost is indeed a valuable product resulting from the enhanced decomposition of organic matter by earthworms and microorganisms. Earthworms play a central role in this process, as they consume organic waste and break it down into smaller particles through their digestive system, aided by a grinding gizzard. They derive nutrition from the microorganisms that proliferate on the decomposing organic matter. The end product, vermicompost, is characterized by its finely divided, peat-like texture. It possesses several desirable properties, including high porosity, excellent aeration, good drainage, and high water-holding capacity. These qualities make vermicompost a highly beneficial soil amendment, enhancing soil structure and fertility while promoting plant growth and health (Edwards and Burrows, 1988) [2].

Biochar application in agriculture involves the use of a form of charcoal produced from organic materials through a process called pyrolysis. Biochar is renowned for its ability to enhance soil fertility, improve crop yields, and mitigate environmental issues. Biochar serves as a valuable soil amendment, improving soil structure, porosity, and water retention. Its porous structure provides habitat for beneficial microorganisms and enhances soil aeration, promoting root growth and nutrient uptake by plants.

Keeping in view the present investigation undertaken the experiment entitled "Effect of organic and inorganic fertilizers on growth and yield of sunflower (*Helianthus annuus* L.) in *rabi* season".

Materials and Methods

The field experiment was carried out during *rabi* 2022 at Experimental Farm of College of Agricultural Biotechnology, Latur to study the Effect of organic and inorganic fertilizers on growth and yield of sunflower (*Helianthus annuus* L.) in *rabi* season. The soil was black with clayey in texture, slightly alkaline in reaction having pH (7.48), low in available nitrogen (125.44 kg ha^{-1}), medium in available phosphorus (12.50 kg ha^{-1}), very high in available potassium (327.41 kg ha^{-1}) and field topography was uniform levelled, well drained and favourable for optimum crop growth. The mean of meteorological data during the experimental period presented in Table 3.2. This data indicated that mean maximum temperature during crop growth period is 30.59 °C while the mean minimum temperature is 12.53 °C. The mean humidity during morning is 81.46% while mean humidity during evening is 43.01%.

The experiment was laid out in randomized block design with three replications and eleven treatments. The treatment includes T_1 – Control, T_2 - Biochar (2.5 t ha^{-1}), T_3 - Biochar (5.0 t ha^{-1}), T_4 - Vermicompost (2.5 t ha^{-1}), T_5 - Biochar (2.5 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}), T_6 - Biochar (5.0 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}), T_7 - RDF 100%, T_8 - RDF 100% + Biochar (2.5 t ha^{-1}),T_9 - RDF 100% + Biochar (5.0 t ha^{-1}), T_{10} - RDF 50% + Biochar (2.5 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}), T_{11} - RDF 50% + Biochar (5.0 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}).

The gross and net plot size of each experimental unit was 5.4 m x 4.5 m and 4.2 m x 3.9 m, respectively. Sowing was done by dibbling method on 20th November, 2022 at spacing of 60 x 30 cm. The recommended cultural practices and plant protection measures were undertaken. The recommended dose of fertilizer 90:60:30 NPK kg ha^{-1} was applied as per treatments, half dose of nitrogen along with full dose of phosphorus and potassium applied as basal dose through urea, single super phosphate and muriate of potash. The remaining half dose of nitrogen was applied one month after sowing through urea as top dressing. The application of Biochar and vermicompost were taken as per the treatments and applied before sowing the seed. The crop was harvested on 10th March 2023.

Methodology

Seed yield (kg ha^{-1})

Heads from each net plot were cut, rubbed against ground and seeds were separated and cleaned by winnowing. Weight of sundried seed kg net $plot^{-1}$ was recorded and presented in kg ha^{-1}.

Stalk yield (kg ha^{-1})

Sunflower stalks harvested from each net plot were sun dried for a week and weight was recorded and converted into kg ha^{-1}.

Biological yield (kg ha^{-1})

It was recorded by formula:

Biological yield = Seed yield + straw yield.

Harvest index (%)

Harvest index indicates the efficiency of plant material to convert the photosynthate in to the economic yield and it is worked out as

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield of respective plot (kg ha}^{-1}\text{)}} \times 100$$

Where,
Biological yield = Head weight + stalk yield
Stalk yield = Stalks + leaves

Economics of sunflower cultivation

Gross monetary returns (₹ha^{-1})

The gross monetary returns occurred due to different treatments in the present study, were worked out by considering the market prices of seed yield of sunflower during the experimental year.

Cost of cultivation (₹ha^{-1})

The cost of cultivation of each treatment was worked out by considering the prices of variable inputs *viz*., labour, fertilizer, seed, bullock charges, machinery charges and plant protection.

Net monetary returns (₹ha^{-1})

The net monetary returns of each treatment were worked out by deducting the cost of cultivation of each treatment from the gross monetary returns gained from the respective treatments.

Benefit: Cost ratio

The benefit: cost ratio of each treatment was calculated by dividing the cost of cultivation to gross monetary.

Results and Discussion

Effect of treatments

The effect of application of 100% RDF combination with biochar and vermicompost to different treatments was observed on important yield parameters *viz.*, seed yield (kg ha^{-1}), stalk yield (kg ha^{-1}), biological yield (kg ha^{-1}), harvest index (%), GMR, CC, NMR, B:C ratio etc, under study.

Yield and yield attributes

Seed yield (kg ha^{-1})

Data showed that treatments were differed significantly with each other in respect to seed yield. The mean seed yield due to different treatments was (1405 kg ha^{-1}).

The application of 100% RDF + Biochar (5.0 t ha^{-1}) (T_9) recorded significantly higher mean seed yield (2435 kg ha^{-1}) which was found significantly superior over rest of treatments under study. The results are confirmative with the finding of Lipi *et al.* (2023) [15] and Ashoka and Shashadhar (2020) [6]

Stalk yield (kg ha^{-1})

Data on stalk yield (kg ha^{-1}) was influenced significantly due to different treatments After harvest of crop, the mean stalk yield was recorded 3688 kg ha^{-1}. The application of RDF 100% + Biochar (5.0 t ha^{-1}) (T_9) recorded highest stalk yield (5739 kg ha^{-1}) and was found at par with application of RDF 100% + Biochar (2.5 t ha^{-1}) (T_8) and only RDF 100% (T_7) and which was significantly superior over rest of treatments under study. Similar results are reported with the finding of Lipi *et al.* (2023) [15] and Bhusari *et al.* (2018) [7].

Biological yield (kg ha^{-1})

Data on biological yield was influenced significantly due to different treatments. The mean biological yield (5092 kg) ha^{-1} was recorded after harvest of crop. The application of RDF 100% + Biochar (5.0 t ha^{-1}) (T_9) recorded highest biological yield (8174 kg ha^{-1}) and was found at par with application of RDF 100% + Biochar (2.5 t ha^{-1}) (T_8) and only RDF 100% (T_7) and which was significantly superior over rest of treatments under study. Similar results are reported with the finding of Lolamwad *et al.* (2021) [16]

Harvest index (%)

The application of RDF 100% + Biochar (5.0 t ha^{-1}) (T_9) recorded highest harvest index (29.79%) followed by application of Biochar (5.0 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}) (T_6). The mean harvest index was 27.57 (%). The present finding are in collaborative with those of Bhusari *et al.* (2018) [7] and Abumere *et al.* (2019) [4].

Economics

Gross monetary return (₹ ha^{-1})

The mean gross monetary return obtained from sunflower crop was 94947 ₹ ha^{-1}. Due to the application of RDF 100% + Biochar (5.0 t ha^{-1}) (T_9) (164606 ₹ ha^{-1}) obtained highest GMR which was found significantly superior over rest of treatments under study. The results are confirmative with the finding of Ashoka and Shashadhar (2020) [6].

Cost of cultivation (₹ ha^{-1})

The highest cost of cultivation (58990 ₹ ha^{-1}) required for the application of RDF 50% + Biochar (5.0 t ha^{-1}) + Vermicompost (2.5 t ha^{-1}) (T_{11}). The lowest cost of cultivation required for the treatment (T_1) control was (35500 ₹ ha^{-1}). The mean cost of cultivation for different treatment was (48040 ₹ ha^{-1}).

Net monetary return (₹ ha^{-1})

The application of 100% RDF + Biochar (5.0 t ha^{-1}) (T_9) was received highest NMR (112121 ₹ ha^{-1}) which was found significantly superior over rest of treatments under study. Similar results are reported with the finding of Dambale *et al.* (2018) [9] and Chitale *et al.* (2004) [8].

Benefit: cost ratio

The highest B:C ratio (3.14) was obtained with the treatment (T_9) application of RDF 100% + Biochar (5.0 t ha^{-1}) among the different fertilizer followed by application of RDF 100% + Biochar (2.5 t ha^{-1}) (T_8). The mean B:C ratio was observed as 1.95 due to various treatments. The results are confirmative with the finding of Khatik and Dikshit (2001) [12]

Table 1: Seed yield (kg ha^{-1}), Stalk yield (kg ha^{-1}), Biological yield (kg ha^{-1}) Harvest Index (%), GMR, CC, NMR, B:C ratio of sunflower as influenced by different treatments.

Treatments	Yield attributes				Economics			
	Seed yield (kgha^{-1})	Stalk yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)	GMR	CC	NMR	B:C ratio
T_1 - Control	701	2008	2710	25.88	47410	35500	11910	1.34
T_2 - Biochar (2.5 t ha^{-1})	875	2275	3151	27.78	59173	40500	18673	1.46
T_3 - Biochar (5.0 t ha^{-1})	981	2433	3415	28.74	66338	45500	20838	1.46
T_4 - Vermicompost (2.5 t ha^{-1})	921	2460	3380	27.24	62237	45500	16737	1.37
T_5 - Biochar (2.5 t ha^{-1}) + Vermicompost (2.5 t ha^{-1})	1050	2643	3694	28.44	71003	50500	20503	1.41
T_6 - Biochar (5.0 t ha^{-1}) + Vermicompost (2.5 t ha^{-1})	1186	2933	4119	28.79	80174	55500	24674	1.44
T_7 - RDF 100%	1905	5474	7379	25.82	128778	42485	86293	3.03
T_8 - RDF 100% + Biochar (2.5 t ha^{-1})	2147	5672	7819	27.46	145137	47485	97652	3.06
T_9 - RDF 100% + Biochar (5.0 t ha^{-1})	2435	5739	8174	29.79	164606	52485	112121	3.14
T_{10} - RDF 50% + Biochar (2.5 t ha^{-1}) + Vermicompost (2.5 t ha^{-1})	1540	4349	5888	26.15	104081	53990	50091	1.93
T_{11} - RDF 50% + Biochar (5.0 t ha^{-1}) + Vermicompost (2.5 t ha^{-1})	1708	4581	6289	27.16	115483	58990	56493	1.96
SE±	68.37	197.62	232.98	-	4621.64	-	4621.64	0.09
CD @5%	204.94	592.41	698.40	-	13854.21	-	13854.21	0.28
General Mean	1405	3688	5092	27.57	94947	48040	46453	1.95

Plate 1: Drone View Experimental plot

Plate 2: Front View Experimental plot

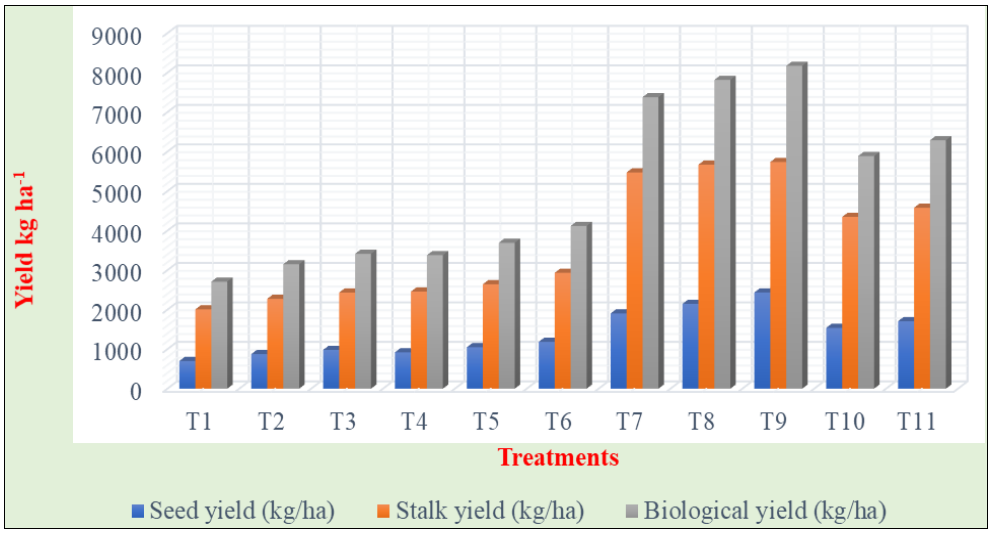

Fig 1: Seed yield, stalk yield, biological yield (kg ha^{-1}) of sunflower as influenced by different treatments at harvest

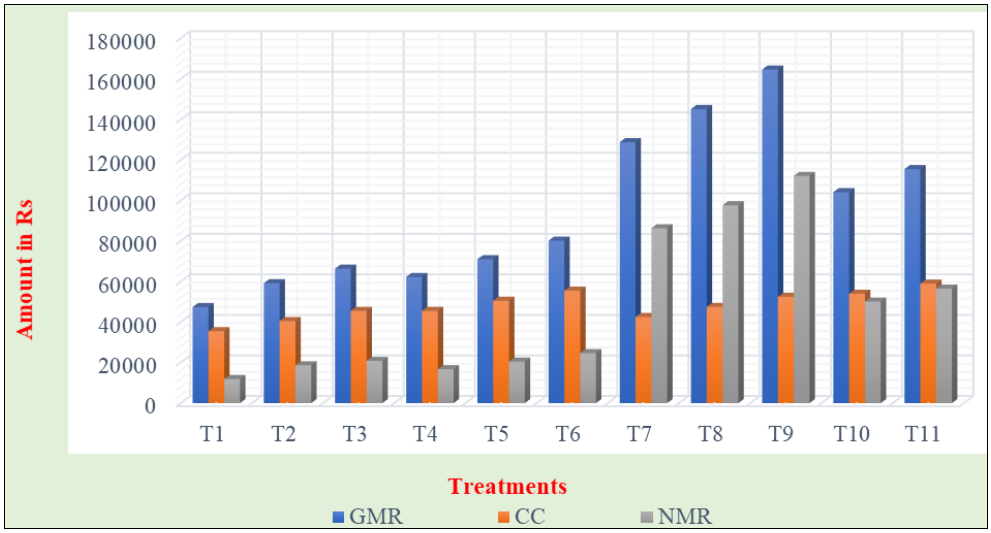

Fig 2: Economics (₹ ha^{-1}) of sunflower crop cultivation as influenced by various treatments

Conclusion

1. The application of RDF 100% + Biochar (5.0 t ha^{-1}) (T_9) recorded highest yield attributes higher seed yield, stock yield, biological yield, test weight, oil yield and number of filled seed plant^{-1}.
2. The highest GMR (164606 ₹/ha), NMR (112121 ₹/ha) and B:C (3.14) ratio was obtained with RDF 100% + Biochar (5.0 t ha^{-1}) (T_9).

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Conflict of Interests

The authors have declared no conflict of interests exist.

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